Seasonal Variation of Food Consumption and Selected Nutrient Intake in Linxian, a High Risk Area for Esophageal Cancer in China[1]

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Abstract: Linxian, China, is a region with high incidence of esophageal cancer and a history of poor nutritional status. Nutrition Intervention Trials were conducted in this area from 1985 through 1991 and found a reduction in total cancer mortality in the group receiving supplementation of β-carotene/selenium/α-tocopherol. The positive results of those trials have, in part, been ascribed to the poor nutritional status of this population. To investigate more recent food patterns, nutrient intakes, and seasonal variations in the diet, dietary surveys were conducted among the residents of Linxian in 1996. Food consumption data were collected among 104 households in spring and 106 households in autumn using a method of food inventory changes. Intake of nutrients was estimated and compared to the Chinese Recommended Dietary Allowance (RDA). In both seasons, the five most common food groups consumed were cereals, fresh vegetables, yams, seasonings, and eggs. Low nutrient intakes were found for selenium (79% RDA and 66% RDA), zinc (72% RDA and 62% RDA), vitamin B_2 (64% RDA and 52% RDA), and calcium (53% RDA and 39% RDA) in both spring and autumn. A large seasonal variation was seen in the consumption of leafy vegetables, root vegetables and eggs, all of which might have contributed to the lower intake of vitamin A (25% RDA), vitamin C (75% RDA), protein (76% RDA), and vitamin E (78% RDA) in autumn. These indicate that the nutrient intake in Linxian is inadequate for a number of vitamins and minerals including those shown to be associated with esophageal cancer.

Key words: Diet surveys, food habits, vegetables, micronutrients, esophageal neoplasm

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Introduction

Linxian, a county in northern China, is well known for the high risk for esophageal cancer (including squamous cell carcinoma of the esophagus and adenocarcinoma of gastric cardia, referred to as esophageal cancer throughout this report) and low nutritional status [1–8]. In the 1970s and 1980s, the dietary intake of the Linxian residents was assessed using standard questionnaires for specific food consumption [1, 7] and food allocation records for specific nutrients [4, 6]. The results from the early studies showed that the residents of Linxian consumed diets with a limited variety of food, and moreover, foods were more likely to be contaminated with carcinogenic components [1, 9–10]. Low consumption of fresh fruits, vegetables, food from animal sources, oil or fat, and low intakes of vitamins A, C, and B_2, and calcium, were found in this population [1, 4, 6–7]. In particular, those surveys found the median consumption of fresh green, orange, or yellow vegetables was just nine times per month in the spring, and 13 to 30 times per month in the other seasons [7]. In the mid-1980s, it was shown that low plasma levels of multiple nutrients in the residents of Linxian were consistent with low dietary intake of fruits and vegetables [1, 3–8].

From 1985 to 1991, two Nutrition Intervention Trials (NIT) were conducted among 40 to 69 year-olds who were residents in rural Linxian [8, 11–15]. The Dysplasia Trial (DT) was carried out among residents with cytological evidence of dysplasia of the esophagus [8, 12–15]. The General Population Trial (GPT) was carried out among residents in the general population of Linxian who had no symptoms of esophageal disease [8, 11–12]. The active treatment group in DT received a supplementation of 26 vitamins and minerals at a dosage of two to three times the Recommended Dietary Allowance (RDA) of the United States. Lower risks of hypertension and cerebrovascular disease and a significant increase in reversion to nondysplastic esophageal cytology were observed among the DT participants who received supplementation of multiple vitamins and minerals [12–15]. The GPT was a partial factorial design. Supplementation included eight groups from each of the four combinations: A: retinol (5000 IU)/zinc (22.5 mg); B: riboflavin (3.2 mg)/niacin (40 mg); C: ascorbic acid (120 mg)/molybdenum (30 µg); D: β-carotene (15 mg)/selenium (50 µg)/α-tocopherol (30 mg). At the end of the GPT, a 9% reduction in total mortality, a 13% reduction in total cancer mortality, and a 21% reduction in stomach cancer mortality were found in participants who received β-carotene/selenium/α-tocopherol supplementation [11–12]. These results strongly suggested the possibility of reducing the risk of cancer and other chronic diseases by increasing intake of certain micronutrients in this population.

Since 1985, little information has been published addressing dietary characteristics of the residents in this population. In this paper we present results from a 1996 assessment of nutritional intake in Linxian that used the food disappearance method established for rural Chinese populations [16]. Our goal is to assess the overall nutritional adequacy of the diet as well as contribution of seasonal variation to nutrient and food intake in Linxian. Since both the intervention [11–15] and other studies we have completed [17–19] indicate that inadequate nutrition or low consumption of fresh vegetables contributed to the high cancer rate in Linxian, current nutritional status has important public health implications. In addition, due to the addition of selenium values to the Chinese Food Composition Tables [20] and our results from two seasons of a year, we are able for the first time to calculate dietary selenium intake for the GPT population.

Methods

Study design and subjects

In 1996, as part of a post-trial mortality assessment, we conducted a survey among all the living participants from the GPT. As one component of that study we conducted a food assessment survey using a household-based food disappearance method (three-day food inventory change) that has been shown to be a useful assessment of dietary intake in rural Chinese populations [16]. To select participants in this study, a two-stage sampling method was used. First, one village was randomly selected from each of four communes in northern Linxian (Baotai village from Rencun, Shengjiabo from Yaocun, Dongluzai from Donggang, and Xixiayuan from Hengshui), where high risk for esophageal cancer was found and the GPT was conducted. Then, households in the four selected villages that included persons who participated in the GPT, and who were currently less than 75 years of age and had no self-reported health abnormalities, were invited to be participants in the study. Informed consent was obtained from each of the GPT subjects before the survey was conducted. The surveys were conducted in spring (April 7 to April 22) and autumn (September 9 to September 22) of 1996.

The major demographic characteristics of the participants are presented in Table I. In total, there were 104 households from 117 invited households in spring and 106 households from 113 invited households in autumn that were surveyed with complete dietary records. Each household included at least one GPT participant; in total, 134 GPT participants' households were recruited in the two seasons. Seventy-six households participated in both spring and autumn surveys, 28 households in the spring

Table I: Characteristics of the households and the participants by season

Characteristics	Spring	Autumn
Household		
Total households	104	106
Baotai of Rencun	24	26
Shengjiabo of Yaocun	26	25
Dongluzai of Donggang	25	29
Xixiayuan of Hengshui	29	26
GPT subject		
Gender – male, %	34.9	40.2
Age – Mean (SD), year	56 (6)	57 (6)
Number by age group (%)		
35–44	3 (2.9)	3 (2.8)
45–64	89 (85.6)	96 (90.6)
>= 65	12 (11.5)	7 (6.6)
Participant		
Total participants	341	331
Average age, year (SD)	39 (21)	40 (21)
Total person-day	884	912
Person-day/household (SD)	8.5 (3.9)	8.6 (4.4)
Participants by age group, year (%)		
< 10	46 (13.5)	39 (11.8)
10–17	26 (7.2)	24 (7.6)
18–44	94 (27.6)	90 (27.2)
45–64	152 (44.6)	159 (48.0)
> 65	23 (6.7)	19 (5.7)

survey only, and 30 households in the autumn survey only. The average age of the head of household was 56 years in spring and 57 years in autumn; the average age of the household member was 39 years in spring and 40 years in autumn.

Food consumption measurement

The method of three-day food inventory change [16] was used in this study. Food consumption measurements were carried out by two teams, each consisting of two data collectors (at least one technician or specialist from the Cancer Institute, Chinese Academy of Medical Sciences) and a guide from the local village clinic or village administrative office. Each team visited the households of the same participants twice in each study season to collect data on total food consumption and the number of persons consuming the foods. At the first visit, each item of food to be consumed in the study household was weighed separately with a portable scale. After three days, a second visit was made to the same households. The leftover foods were weighed again. The differences of the two measurements were considered to be the food consumed in the study period. Additional foods consumed during that period were estimated by the participant or the housewife of the household and were added to the total food consumption values. Information on the number of meals, age, and gender of the consumers was also collected. Household consumption was estimated as the disappearance of foods over the three surveyed days. Daily consumption of the head of household *(per capita)* was estimated from the total household consumption and total person-days. Children younger than three were excluded from estimation for total number of consumers.

Food consumption data were linked with Chinese Food Composition Tables to estimate nutrient intake. Nutrient values for foods from areas near Linxian were selected as the reference values in the calculation. Because retinol equivalence (RE) is provided as a combination of vitamin A (from animal sources) and pre-vitamin A (from plant foods, such as β-carotene) in the Chinese RDA (Table II), the intakes of these two nutrients were all transformed to RE (1 μg vitamin A equals 1 μg RE, 1 μg β-carotene equals 0.167 μg vitamin A which equals 0.167 μg RE) in this report.

Statistical Analysis

The assessment of dietary nutritional status was focused on the NIT subjects who were the heads of the households. *Per capita* means for food consumption (foods and/or food groups) and nutrient intake were calculated for the head

Table II: Recommended dietary allowances of selected nutrients for Chinese men and women[1]

Nutrient (Unit), Daily *per capita*	Age groups (year) 18–44	45–79
Protein (g)		
Male	80	70–75
Female	70	65–70
Fat (% energy)	20–25	20–25
Calcium (mg)	800	800
Iron (mg)		
Male	12	12
Female	18	12
Zinc (mg)	15	15
Selenium (μg)	50	50
Vitamin A (μg)	800	800
Vitamin B_1 (mg)		
Male	1.3	1.2
Female	1.2	1.2
Vitamin B_2 (mg)		
Male	1.3	1.2
Female	1.2	1.2
Niacin (mg)		
Male	13	12
Female	12	12
Vitamin C (mg)	60	60
Vitamin E (mg)	10	12

[1] Cited from Institute of Nutrition and Food Hygiene, Chinese Academy of Preventive Medicine (1988, ref 21); for both men and women if not specified; light physical exercise.

of each household. *Per capita* seasonal means and 95% confident intervals (CI) were calculated by averaging the *per capita* household means. The average daily nutrient intake was compared to the reference nutrient value of Chinese RDA that was specified for the age and gender of the household's head. Nutrient intake of less than 80% RDA is considered as low in this study. Seasonal differences in mean food consumption (with log-transformation) and nutrient intake were considered statistically significant at $p < 0.05$ by independent-samples t-test (two-sided).

Results

A total of 79 different foods were consumed in the study periods (1796 person-days: 884 person-days in spring and 912 person-days in autumn). Table III lists relative frequency (at least once during the study period by 5% of households) of foods consumed, by season and food group. Common foods identified included cereals (wheat, rice, millet, and corn), fresh vegetables (leafy vegetables, root vegetables, green beans, squashes, and vegetable fruits), yams (potato and sweet potato), eggs (chicken eggs), seasoning (salt, soy sauce, and vinegar), cooking oil (cottonseed oil), pickled vegetables (cabbage), beans/bean products (soybean and bean curd), meat (pork), and fresh fruits (apples and pears). There was no significant difference found in the overall consumption of most food groups between the two surveyed seasons, but seasonal differences were seen in the consumption of yams, bean products, fresh fruits, and subgroups of fresh vegetables. Leafy greens, root vegetables, sweet potato, and bean curd were consumed more frequently in the spring than in autumn, while green beans, squash, vegetable fruits, and pears were consumed more frequently in autumn than in spring.

Table III: Common foods consumed in Linxian, spring and autumn, 1996

Group	Food	Spring	Autumn
Cereal	Wheat, rice, millet, corn	+	+
Fresh vegetables		+	+
Leafy	Spinach	+	–
	Chinese cabbage	+	–
	Garlic leaf	+	–
	Bean sprout	+	–
Root	Radish	+	–
	Carrot	+	–
Green beans	Green beans	–	+
Squash	Squash, cucumber	–	+
Vegetable fruits	Eggplant, tomato	–	+
	Green pepper	–	+
Yams	Potato	+	+
	Sweet potato	+	–
Eggs	Chicken egg	+	+
Seasoning	Salt, soy sauce, vinegar	+	+
Cooking oils	Cotton seed oil	+	+
Pickled vegetables	Cabbage	+	+
Bean/bean products	Soybean	+	+
	Bean curd	+	–
Meat	Pork	+	+
Fresh fruits	Apple	+	+
	Pear	–	+

+ Consumed by 5% or more of households surveyed.
– Consumed by less than 5% of households surveyed.

Table IV shows the average daily consumption, by season and food group. Total daily food consumption per person was 1054 gram (g) in the spring and 1035 g in autumn. In both spring and autumn combined, from highest to lowest consumption, the foods consumed by food group were cereals, followed by fresh vegetables, yams, seasonings, eggs, cooking oil, pickled vegetables, beans/bean products, meat, and fresh fruits. Significant seasonal differences were observed for daily consumption of subgroups of fresh vegetables, with high consumption of leafy vegetables in the spring and more green beans, squashes, and vegetable-fruits eaten in the autumn.

Cereals and fresh vegetables were the main sources for most nutrients, while cooking oil contributed to the majority of the vitamin E and fat. Foods from animal sources accounted for less than 8% of all nutrients studied. Ninety-three percent of vitamin A was from plant sources, while 75% of selenium and 76% of zinc were from cereals.

Table V shows the average daily intake *per capita* of energy and thirteen nutrients in the diet of study subjects, and compared the *per capita* means to the Chinese RDA specified for the age and gender of the household heads by season. Low intakes, especially in autumn, were found for selenium, zinc, vitamin B_2, and calcium. A significant seasonal difference was observed in the intake of vitamin A ($p < 0.001$), vitamin C ($p < 0.001$), vitamin E ($p < 0.05$), as well as selenium ($p < 0.01$), zinc ($p < 0.01$), and vitamin B_2 ($p < 0.01$) between spring and autumn. The average intake of energy, iron, vitamin B_1, and niacin were all above 80% of the RDA. The average intake of fat was less than 80% RDA in both seasons, while the average intake of protein in autumn was less than 80% RDA and lower than spring ($p < 0.05$).

Discussion

The primary goals of this study were to assess current dietary intake of middle-aged residents in Linxian, and to compare this to results from earlier studies that found low dietary intakes of multiple nutrients. Using a more precise and informative method than the measurement used in ear-

Table IV: Per capita average daily consumption by food group and season in Linxian, 1996

Food group	Average daily consumption (g/capita) Spring (N = 104 household)		Autumn (N = 106 household)	
	Mean	(95%CI)	Mean	(95%CI)
Cereals	501	(468–534)	482	(452–512)
Fresh vegetables	396	(352–440)	407	(366–448)
Leafy***	248	(208–288)	39	(26–52)
Roots	146	(116–176)	64	(47–81)
Green beans*	2	(1–5)	75	(56–94)
Squashes*	0		184	(147–221)
Vegetable fruits*	0		45	(30–60)
Yams	57	(40–74)	63	(46–80)
Seasonings	37	(29–45)	38	(32–44)
Eggs	31	(23–39)	7	(3–11)
Cooking oil	18	(14–22)	19	(15–23)
Pickled vegetables	5	(1–9)	1	(0–2)
Beans/bean product	4	(1–7)	1	(0–2)
Meat	2	(0–4)	3	(1–7)
Fresh fruits	3	(0–6)	14	(4–24)

CI: 95% confidence interval.
P values of seasonal differences of means (with log transferred) by independent samples *t*-test (two-sided) were < 0.05 (*) and < 0.001(***).

Table V: Per capita average daily intake of energy and nutrients, percentage of Chinese RDA by season in Linxian, 1996

Nutrient (unit)	Spring (N = 104 Household) Mean	95%CI	% RDA	Autumn (N=106 Household) Mean	95% CI	% RDA
Energy (kcal)	2285	(2160–2410)	102	2195	(2060–2330)	96
Carbohydrate (g)	398	375–421)	N/A	383	(358–408)	N/A
Protein (g)*	61	(57–65)	86	54	(50–58)	76
Fat[1] (% of energy)	15	13–15)	59–74	15	(14–16)	58–73
Iron (mg)**	26	(24–28)	216	22	(20–24)	187
Vitamin B_1 (mg)	2.3	2.2–2.4)	192	2.3	(2.1–2.5)	189
Niacin (mg)	14	(13–15)	116	14	(13–15)	105
RE[2] (μg) ***	1234	(999–1469)	154	201	(166–236)	25
Vitamin C (mg)***	107	(93–121)	156	52	(45–59)	75
Vitamin E (mg)*	11	(10–12)	95	9	(8–10)	78
Selenium (μg)**	39	(36–42)	79	33	(31–35)	66
Zinc (mg)**	11	(10–12)	72	9	(8–10)	62
Vitamin B_2 (mg)**	0.8	(0.7–0.9)	64	0.7	(0.6–0.8)	52
Calcium (mg)***	422	(388–456)	53	314	(288–340)	39

[1] 20%–25% of energy served as referent RDA.
[2] Retinol Equivalence.
P values of seasonal differences of means by independent samples *t*-test (two-sided) were < 0.05 (*), < 0.01 (**), or < 0.001(***).
N/A: Not applicable.

lier studies [1, 4, 6–7], lower intakes of selenium, zinc, vitamin B_2, and calcium in both spring and autumn, and low intake of vitamins A, C, and E, and protein in autumn were observed in the present study. Seasonal variations were found by subgroups of fresh vegetable consumption, possibly contributing to differences in intake of several nutrients.

One potential limitation of the method used in the present study is that the measured dietary intake is based on the aggregate consumption of a family rather than data on individual level consumption. Since nearly all foods are consumed in family meals, sources of nutrition from outside the home are unlikely to play a significant role in the overall accuracy of the familial measurement. Assuming the average household consumption to be equivalent to the consumption of the head of household (the selected GPT follow-up subject) could have underestimated the per-household consumption because young children ate less. To minimize the impact of this problem we excluded all individuals under three years of age. The nutritional requirements according to the Chinese RDA for most vitamins and minerals (such as vitamins A, B_2, C, and E, and selenium, zinc, and calcium) are a little different for men and women, with light physical activity assumed for persons aged 18 through 79 years, which covered over 97% of the heads of the households (the GPT subjects) or 75% of all consumers in the study. Differences in age requirements are unlikely to have influenced the overall assessment of nutrients for which intake we found to be low. In this study, over 70% of households participated in both spring and autumn and no significant differences in demographic distribution occurred by season. The measurements of food consumption and selected nutrient intake across seasons are more likely to be comparable in the current study than the earlier studies.

Spring was the season with lowest consumption of fresh fruits and fresh green, orange, or yellow vegetables at or before the mid-1980s in Linxian [1, 7]. In the present study, no significant difference in the average consumption of total fresh vegetables was found between spring and autumn. Moreover, increased consumption of fresh leafy and root vegetables in spring contributed to increased intakes of vitamin C and vitamin A (93% from plant sources). These results reflected some positive changes in the recent diet of Linxian residents.

Dietary intake and seasonal variation of selenium in Linxian was not reported previously because reference values for selenium were unavailable until the publication of the updated version of the Food Composition Tables in 1991 [20]. Selenium intakes reported in this study were consistent across the two surveyed seasons, and should be a close estimate of dietary selenium intake of the study population. In a recent study we found a strong inverse relationship between the serum selenium levels from subjects before the NIT began in 1985, with the subsequent development of esophageal cancer [19]. We estimated that 26% of the esophageal cancer cases in Linxian may be attributed to low selenium status, and suggested that serious consideration be given to population measures to increase selenium intake. Our current finding is that dietary intake of selenium, measured in both spring and autumn, is still below the Chinese RDA. This low intake provides impetus for additional measures to increase selenium intake in this population.

Low dietary intake of vitamin B_2, zinc, calcium, and protein observed in this study is consistent with previous findings in Linxian [4–6]. This may be due to small changes in the lack of dairy and poultry consumption, and low consumption of beans and animal food in the traditional Linxian diet. An increase in consumption of eggs in the spring might have partly led to the differences in the intake of vitamin B_2, selenium, and protein. Reasons for the seasonal differences in the intake of zinc and calcium were not clear, but may be due to the variable consumption of subgroups of fresh vegetables.

Previous results from intervention studies in Linxian showed decreased cancer mortality and increased reversion of dysplasia to non-dysplasia of the esophagus by multivitamin and mineral supplementation [8, 11–15]. Case-control and ecological studies conducted in the US [22–25], France [26], Greece [27], and China [17–18, 29] have also shown an inverse relationship between the consumption of fresh vegetables or plant food and the risk of esophageal cancer. In the present study, low dietary intakes were found for selenium, zinc, calcium, vitamins A, B_2, C, and E, and protein, though not in all surveyed seasons, in Linxian. Strategies for improving the nutritional status of this population, including food selection, increasing food availability, food fortification, and supplementation of the specific nutrients, should be considered.

Improvements in the local economy and increasing public knowledge about the factors associated with human diseases have been shown to impact lifestyle in Linxian. Daily consumption of pickled vegetables, suspected to be a risk factor for esophageal cancer in Linxian, was common for six to nine months of a year [1]; pickled vegetables were consumed regularly by 43% of study subjects [17] in the 1970s in Linxian. In the mid-1980s, the information from NIT baseline interviews [8] and a nested case-control study in NIT [18] observed that only 10% of study subjects had consumed those foods. In the present study conducted in 1996, the average consumption of pickled vegetables continued to be low in both seasons. These changes may reflect the response of this population to the public health education efforts and introduction of healthy dietary habits in Linxian. Acknowledgment of the relevance and the results of the NIT may have also encouraged the increased availability and consumption of fresh vegetables in this population. Even though not all intakes of nutrients in the present study met the RDA, the large seasonal variations of vitamin C and vitamin A suggested that improving dietary intake by food selection in this area is possible.

In summary, the results of the present study found low dietary intake of multiple micronutrients, including selenium, zinc, vitamin B_2, and calcium in both spring and autumn, and low intake of vitamin A, vitamin C, protein, and vitamin E in autumn in recent diets of the Linxian residents. Increasing food variety and consumption of fresh vegetables may be one of most feasible approaches to improve dietary nutritional status. Improvement of dietary nutritional status in Linxian should be still a priority.

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